

CLAIMS

1. A mixing apparatus for mixing fuel and air for combustion in a gas turbine, the mixing apparatus comprising a body having a mixing channel for mixing fuel and air for combustion, the mixing channel having a main channel portion and a distinct insert channel portion, a fuel inlet being located on the insert channel portion.
2. A mixing apparatus as claimed in claim 1 in which the primary inlet is located in a portion of the insert channel portion having a curved, preferably elliptic, more preferably circular, cross section.
3. A mixing apparatus as claimed in claim 1 or claim 2 in which the insert channel portion comprises a plug.
4. A mixing apparatus as claimed in claim 3 in which the insert channel portion comprises a plug attached to one end of the main channel portion.
5. A mixing apparatus as claimed in claim 3 in which the plug is threaded for location thereof at the end of the main channel portion.
6. A mixing apparatus as claimed in claim 3 or claim 4 or in claim 5 in which the plug is removable from the body.
7. A mixing apparatus as claimed in any preceding claim in which the insert channel portion comprises a pre-calibrated insert of the mixing channel.
8. A mixing apparatus as claimed in any of claims 1 to 7 in which the mixing channel has a circular or otherwise curved cross section upstream portion thereof and a transition portion merging to an exit portion with a

rectangular cross section.

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9. A mixing apparatus as claimed in claim 8 in which the upstream portion of the mixing channel is tilted relative to the exit portion thereof.
10. A mixing apparatus as claimed in claims 8 and 9 in which the rectangular cross section has a wall aligned with and leading into a flat back plate surface of the body.
- 10 11. A mixing apparatus as claimed in claim 4 or any preceding claim when dependent thereon in which the plug has several primary inlets spaced therearound.
- 15 12. A mixing apparatus as claimed in any preceding claim in which the mixing channel has a bell-mouth entrance.
- 20 13. A mixing apparatus for mixing fuel and air for combustion in a gas turbine, the mixing apparatus comprising a body having a mixing channel for mixing air and fuel, the mixing channel in one portion thereof having an at least partly curved cross section.
14. A mixing apparatus as claimed in claim 13 in which the cross section is elliptical, preferably circular.
- 25 15. A mixing apparatus for mixing fuel and air for combustion in a gas turbine, the mixing apparatus comprising a body having a mixing channel for mixing air and fuel, the mixing channel having a fuel inlet section which has a plurality of fuel inlets spaced around a periphery thereof.

- 5 16. A mixing apparatus for mixing fuel and air for combustion in a gas turbine engine, the mixing apparatus comprising a body having a dominant axis and at least one mixing channel, the mixing channel having a height in the direction of the dominant axis and a width generally perpendicular to the dominant axis, wherein the mixing channel has a height/width aspect ratio ≤ 2 .
- 10 17. A mixing apparatus as claimed in claim 16 in which the aspect ratio is ≤ 1.5 .
- 15 18. An apparatus as claimed in claim 16 or 17 in which a primary fuel inlet is provided for injecting fuel into the mixing channel along the height direction of the mixing channel.
19. An apparatus as claimed in claim 18 in which the primary fuel inlet is located in the mixing channel.
- 20 20. An apparatus as claimed in any preceding claim in which the mixing channel is generally rectangular in cross section.
- 25 21. An apparatus as claimed in claim 20 when dependent upon claim 18 in which the primary inlet is located on a wall of the mixing channel defining the width of the channel.
22. An apparatus as claimed in one of claims 16 to 21 in which the body has a flat back-plate extending thereacross, the mixing channel having a flat wall co-planner with and leading towards a main surface of the back-plate.

23. An apparatus as claimed in any preceding claim in which the body includes a plurality of said mixing channels.
- 5 24. An apparatus as claimed in claim 23 in which the mixing channels are regularly spaced about a dominant axis of the body.
- 10 25. An apparatus as claimed in claim 23 or claim 24 in which at least one mixing channel has an exit direction orientated at a slant to a radius of the body to induce swirl in flow exiting the body.
26. An apparatus as claimed in claim 23 or claim 24 or claim 25 in which each said mixing channel is straight.
- 15 27. An apparatus as claimed in any preceding claim, which includes a secondary fuel inlet, the secondary fuel inlet being located at a position outside the mixing channel.
- 20 28. An apparatus as claimed in claim 27 in which the body has a central axis and the secondary fuel inlet is located on a back plate of the body between a said mixing channel and the central axis.
- 25 29. An apparatus as claimed in claim 28 when dependent upon claim 25 in which the secondary fuel inlet is located sufficiently close to the central axis to be located in a zone of separated flow caused by swirl induced by the orientation of at least one of the mixing channels.
30. An apparatus as claimed in any preceding claim in which each mixing channel comprises a bore formed in the body of the apparatus.

31. An apparatus as claimed in any preceding claim in which a plurality of primary fuel inlets are provided.
- 5 32. An apparatus as claimed in any preceding claim in which a plurality of secondary fuel inlets are provided.
33. An apparatus as claimed in claim 32 in which the secondary fuel inlets are equi-spaced around a centre of the body.
- 10 34. An apparatus as claimed in claim 32 or 33 in which each secondary fuel inlet is located at a position aligned with a central axis of a said mixing channel.
- 15 35. An apparatus as claimed in any preceding claim in which the secondary fuel inlet comprises an injection pipe angled relative to a central axis of the apparatus for emitting fuel in a direction having a component perpendicular to the central axis.
- 20 36. An apparatus as claimed in any preceding claim in which the secondary fuel inlet is configured so as to emit fuel in a direction having a component aligned with a central axis of a mixing channel of the apparatus.
- 25 37. An apparatus as claimed in any preceding claim in which the secondary fuel inlet has a shield for providing shielded pilot fuel injection.
38. An apparatus as claimed in claim 37 in which the shield configuration conforms to an outflow direction of a mixing channel.

39. An apparatus as claimed in claim 37 or claim 38 in which the shield comprises a circular plate for providing shielded flow in a radially inward direction from under the side plate.

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40. An apparatus as claimed in claim 39 in which the plate includes at least one hole therethrough enabling pilot fuel to flow in an axial direction through said plate.

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41. An apparatus as claimed in any preceding claim, having equal numbers of primary and secondary fuel inlets.

42. An apparatus as claimed in any preceding claim, having fewer secondary fuel inlets than primary fuel inlets.

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43. An apparatus as claimed in any preceding claim, having fewer secondary inlets than mixing channels.

44. An apparatus as claimed in any preceding claim in which the body is circular.

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45. An apparatus as claimed in claim 44 in which the body has a back plate and each mixing channel is formed in a portion of the body upstanding from the back plate on a fuel side thereof.

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46. An apparatus as claimed in claim 45 in which at least one fuel manifold is placed on a second side of the back plate opposite the first side thereof.

47. A mixing apparatus for mixing fuel and air for combustion in a gas

turbine, the mixing apparatus comprising a body having a mixing channel part for mixing fuel and air, a primary fuel inlet; and a secondary fuel inlet; where the secondary fuel inlet is adapted to admit fuel at a location outside the mixing channel part.

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48. A mixing apparatus for mixing fuel and air for combustion in a gas turbine, the mixing apparatus comprising a body having a mixing channel for mixing fuel and air, a primary fuel inlet; and a secondary fuel inlet; when the secondary fuel inlet is adapted to admit fuel inlet is adapted to admit fuel into a zone of separated flow on the body.

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49. *A radial flow swirler for mixing air and fuel for combustion, the swirler having a primary fuel inlet and a secondary fuel inlet, the secondary fuel inlet being configured for direct injection of pilot fuel.*

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50. A swirler for mixing air and fuel for combustion, the swirler having at least one mixing channel, the mixing channel having a bell-mouthed entrance.

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51. A swirler for mixing air and fuel for combustion, the swirler having at least one mixing channel having an entrance passage tilted relative to a plane perpendicular to a central axis of the swirler.

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52. An apparatus for mixing fuel and air for combustion, the apparatus having a primary inlet and a secondary inlet, the secondary inlet being configured to emit fuel in a direction with a component perpendicular to a central axis of the apparatus.

53. An apparatus for mixing fuel and air for combustion, the apparatus

having a primary fuel inlet and a secondary fuel inlet, the secondary fuel inlet comprising a pipe inclined relative to a central axis of the apparatus.

- 5 54. A combustor for burning fuel and air in a gas turbine engine, the combustor incorporating a mixing apparatus as claimed in any preceding claim.
- 10 55. A combustor as claimed in claim 54, which has a cylindrical outer casing wall with an end plate, the mixing apparatus being located centrally on the end plate.
- 15 56. *A combustor as claimed in claim 55 in which an inner combustion line is provided, one end of the liner being connected to the mixing apparatus; an air passage being provided between an outer surface of the liner and the casing wall; an entrance to the mixing channel facing the air passage; an exit from the mixing channel leading to a combustion products passage inside the liner.*
- 20 57. *A combustor as claimed in claim 56 in which the mixing apparatus is adapted to induce swirl inside the combustor, the swirl inducing reverse flow along a central axis of the liner and separation of a boundary layer from a back plate to mixing apparatus downstream of the mixing channel.*
- 25 58. A gas turbine engine including a combustor as set out in any one of claims 55 to 57.
59. A method of calibrating a fuel mixer for mixing fuel and air in a gas turbine, the method comprising providing a fuel/air mixing channel having a fuel inlet device formed with a fuel inlet, calibrating the fuel

inlet device, and then installing the fuel inlet device on to the mixer.

5 60. A method as claimed in claim 51 in which the calibrating of the fuel inlet device includes calibrating the device with respect to fuel flow characteristics thereof.

10 61. A method as claimed in claim 59 or claim 60 in which the calibrating of the fuel inlet device includes calibrating the device with respect to air flow characteristics thereof.

62. A method as claimed in claim 59 or claim 60 or claim 61 in which the fuel inlet section is removably installed on to the mixer.

15 63. A method as claimed in any one of claims 59 to 62 in which the fuel inlet device incorporates a primary fuel inlet of the mixer.

20 64. A method as claimed in any one of claims 59 to 63 which includes installing the fuel inlet device on to an end of a main channel portion of the mixing channel.

65. A method as claimed in any one of claims 59 to 63 in which the mixer comprises a mixing apparatus as set out in any of claims 1 to 53.

25 66. A mixing apparatus substantially as described herein with reference to the accompanying drawings.

67. A combustor substantially as described herein with reference to the accompanying drawings.

68. A gas turbine engine substantially as described herein with reference to the accompanying drawings.
- 5 69. A method of calibrating a mixing apparatus for fuel and air in a gas turbine, the method being substantially as described herein with reference to the accompanying drawings.
- 10 70. An apparatus as claimed in any one of claims 1 to 53 in which one or more secondary fuel inlets are provided shielded by an annular ring coaxial with a central axis of the apparatus discharging pilot fuel in a radially inward direction onto a back wall of the apparatus.
- 15 71. An apparatus as claimed in claim 18 in which the primary fuel inlet is located at a position upstream of the mixing channel.
- 20 72. A swirler for mixing fuel and air for combustion, the swirler having at least one mixing channel, wherein the mixing channel has a circular cross section.
- 25 73. A swirler as claimed in claim 72 in which the mixing channel leads to a toroidal chamber.
74. A swirler for mixing fuel and air for combusting, the swirler having at least one mixing channel, wherein the mixing channel leads to a toroidal chamber.
75. A swirler as claimed in claim 73 or claim 74 in which the toroidal chamber has the same height as the height of the mixing channel.

76. A swirler as claimed in claim 73 or claim 74 or claim 75 in which the toroidal chamber has an exit leading to a cylindrical pre-combustion chamber.

5 77. A swirler as claimed in any one of claims 72 to 73 in which the channel along its full length conforms to the shape of a circular cylinder.

78. A swirler as claimed in any one of claims 72 to 77 in which the mixing channel has a bell-mouthed entrance.